COCKPIT VISION: ENHANCED COMMUNICATIONS WITH AIRCRAFT PILOTS VIA SATELLITE

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ABSTRACT

Pictures or imagery are a highly effective form of communications. While plans are progressing for introduction of individual video screens at passenger seats in commercial airlines, less attention has been directed at the possibilities of picture delivery for enhancement of command and control, flight safety, and operational communications to the flight deck; that is, the presentation of critical information to *flight crews* as imagery and graphics rather than as voice (audio) or text message displays.

The term *cockpit vision* is meant to imply a threefold meaning: the introduction of visual displays, the resulting enhanced pilot vision of the aircraft environment, and the visionary application of technology to flight deck communications. This paper provides a conceptual outline of the application of emerging desktop computer video image capture, image compression, and compact high-resolution color display in the cockpit for the effective and efficient presentation of weather, air traffic control and other data to the pilot or flight crew. The contemporary improvement in satellite communications to aircraft, and deployment of improved weather collection and dissemination systems, coupled with a visual output display, makes a significant advance in operational communications possible. This paper shows through examples how visual output of graphics, including maps and imagery, could be used to advantage in the cockpit, not only to replace text, but to provide an improved systems interface to sensors providing real-time information.

INTRODUCTION

Current operational problems with commercial and military aircraft include maintaining or reducing congested corridor space (lateral, vertical, and along track) to improve system air traffic capacity; changing flight trajectory in response to changes in weather and winds; and improving flight safety.

In the northeast corridor (North America to Europe), aircraft spacing of 5 minutes along track, 30 miles between adjacent tracks, and 2,000 feet in altitude between flight planes is met using a variety of techniques and systems. Real-time satellite communications and other enhancements are needed to reduce these spacings for greater airspace capacity, and to add more dynamic flight management for fuel savings without loss of safety.

EXPANDED PASSENGER COMMUNICATIONS

Video to Passengers

External communications service for airlines passengers was introduced with the installation of pay telephone services on large aircraft. Still not universally available, this service has nevertheless proven valuable to users and has served to identify a viable market. Consequently, international maritime satellite (INMARSAT) is anticipating introduction of multiple channel terminals (i.e., four simultaneous accesses) for aircraft. Over 200 commercial aircraft now provide single-channel access.

Courtesy Hunting Avionics, England

Figure 1. Passenger Seat Monitor Unit

Communal passenger viewing of video presentations has been common on long distance flights for two decades. Introduction of individual viewing screens has begun for presentation improvement and allows program selection from a menu of several options. In addition, in-flight video merchandise shopping may be implemented on one channel. This concept will enable new markets in entertainment and retail sales. It also foreshadows interactive computer communications availability to the passenger. The new capability turns on the availability of the solid-state flat panel color displays.

Several airlines have announced plans for introduction of individual color display screens at passenger seats. These plans are summarized in table 1.

Table 1. Survey of Plans for Introduction of Color Displays to Individual Passengers

Airline	Date of Introduction	Reference
Northwest Orient	1993 (announced 1992)	1
TWA	1993	2
United Airlines	1993 (contract 1992)	3
Lufthansa	1994 (trial 1993)	3
Singapore Airlines	unknown	3
China	contract 1992	3
Finnair	contract 1992	3
Swissair	contract 1992	3

A flat panel proposed for such use is shown in figure 1. The display has been edited and represents a union of two products of Hunting Avionics, West Drayton, Berkshire, England. The LCD screen measures 6.1 x 5.8 x 1.5 inches (termed 5.7 inch screen, largest of three models) and provides 240 x 720 pixels. (A touch keyboard has been inserted.)

The introduction of video displays is a significant advancement for individual passenger communications, and the same body of technology could also be applied for improvement of communications between air traffic control, airline operations and the flight crew. Announced plans suggest a disproportionate attention to passenger communications in comparison to that for the cockpit.

KEY TECHNOLOGIES

Introduction of visual displays in the cockpit is enabled by several rapidly advancing technologies. These technologies, including liquid crystal displays, will be briefly outlined.

Liquid Crystal, Flat Panel Color Displays

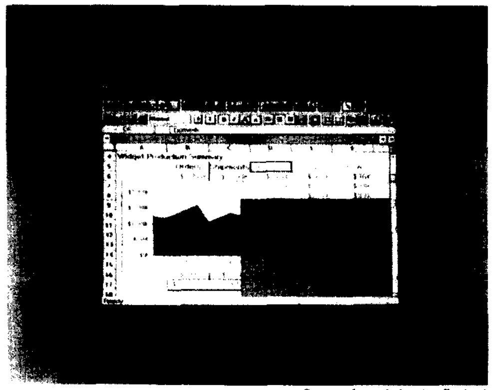
Miniaturization of personal computers produced the laptop computer operated from batteries. First generation products employed monochrome flat-panel liquid displays (LCDs). Current products incorporate color LCDs.

An example packaged LCD product, possibly large enough for the cockpit, is the SEAL Touch flat-panel VGA Module measuring 10.2 inches x 12.26 inches x 2.8 inches, having 640 x 480 pixels, 512 colors and a power consumption of ~42 watts. This display is shown in figure 2. (The SEAL Touch flat panel VGA Module produced by Lucas Deeco, a division of Lucas Automation and Control Engineering, U.S. subsidiary of Lucas Industries plc, Slough, Berkshire, UK. SEAL Touch is a registered trademark of Lucas Automation and Control Engineering Inc.)

Personal Computer Technology

The personal computer, LCDs, compact disk read-only memory (CD-ROM) and digital still-video technology are applicable to *cockpit vision.*

CD ROM provides ability to store maps in various resolutions in the cockpit. This may be employed to obviate transmission of map background data for some displays, reducing data or required data rates for satellite communications.



Courtesy Lucas Industries, England

Figure 2. SEAL TOUCH VGA LCD Unit

Digital still-video technology—including charge coupled device (CCD) cameras, digital frame grabbers, and image compression products—also has potential roles in airborne environments, and is explored in a military context in reference 4. Lightweight CCD cameras produce analog video signals in standard formats. Frame grabbers are implemented in chip sets and, provided as computer boards, convert a video to a still digital picture. The digital file representing the single image can then be reduced in size by image compression. Large compression ratios can be achieved if truly lossless reception is not required. Most applications envisioned for cockpit vision do not require lossless transmission. Furthermore, many applications involve vector graphics that require significantly smaller file sizes (e.g., <100 kbytes).

Computer Supported Mission Planning and Training

Mission planning can be accomplished with computer support and by employing the same or closely related software used for in-flight air traffic control. The mission flight trajectory, en route weather, and other relevant factors can be incorporated into the plan. The plan file can be used to produce automatically a preflight briefing for the flight crew. Although beyond the scope of this paper, it is possible to develop an interactive mission rehearsal using virtual reality technology to enable or enhance preflight training.

Headup Displays

Headup displays may be applicable to in-flight data presentation in single and two place (small) aircraft, but is not considered applicable to large aircraft.

Satellite Communications

Introduction of worldwide L-Band satellite communications service to aircraft can be confidently predicted. INMARSAT terminals are operational on over 200 commercial aircraft, and a number of domestic and regional aeronautical satellite communications systems are in advanced stages of development. Further development of antennas and terminals will seek to reduce equipment and installation costs, while increasing the rate of terminal installation. Thus, the assumed communications with aircraft in flight is via L-Band (~1.6 GHz). Similar capabilities could be implemented using UHF (225–400 MHz) satellite communications for military aircraft. If the L-Band terminal is installed on military aircraft for other reasons, the need for UHF capability might be reduced. UHF has the benefit of low cost omnidirectional antennas, significant operational experience, and lower cost airborne terminals. Graphics and compressed pictorial image file size allow use of modest data rates for a single user. For air traffic control, a number of aircraft could be served by a single multiplexed broadcast channel. Thus, it might be useful to introduce a single broadcast channel for operational control (flight deck communications). Such a channel could have a high burst rate of perhaps 200 kb/s, with time division multiple access. More frequent updates for a danger situation could be accommodated by assigning more time slots.

Advanced Sensors

Weather satellites and ground-based weather radars continue to evolve. Duplication and overlap of data sets by alternative sensors can be used to provide smoothed data.

FLIGHT DECK COMMUNICATIONS ENHANCEMENT

Introduction

Operational functions that could be implemented using LCD output would make use of the more direct and contextual presentation inherent in a graphical or pictorial color display, in contrast to voice or text. While research on the man-machine interface continues, it is clear that the pictorial approach has achieved significant user acceptance in personal computers. Current product developments emphasize desktop video and enhanced multimedia information presentation. This revolution will produce a body of commercial products that may be adapted for use in cockpit visual displays.
Some of the operational functions are discussed in turn.

Presentation of Flight Plan

The flight crew could be presented with a flight plan on the flight deck or in a briefing room prior to flight. The presentation could be computer generated to incorporate up-to-date weather, route congestion, and other data. The preflight briefing could provide mental context for in-flight updates. Common use of technology for development and plan presentation, along with in-flight communications and control, would result in both a more effective overall system and a reduction in training costs (including maintenance).

Presentation of Weather Data

It is significant that systems in use or under development for collecting weather data are all digital, or at least distribute products in digital form. Furthermore, distribution systems are moving increasingly to satellite digital form. For example, the U.S. Federal Aviation Administration now employs a (C-Band) satellite very small aperture system to distribute weather data collected by distributed ground-based weather radars. The data is broadcast and various en route traffic control centers can receive weather data from multiple sites. The control centers generally interested in multiple weather radar outputs are not colocated with the weather radars, and the satellite broadcast has proven cost-effective. Satellite collected weather data is also widely used in aircraft operations, both military and civil. The U.S. Air Force operates the Air Weather Distribution System (AWDS), which collects and processes weather and environmental data, and creates products representing information synthesized from multiple sources.
Figure 3 shows the streamlines or flow of winds over the United States, suggesting westbound flights could choose a flight path presenting lower headwinds. Figure 4 is a lower resolution wind speed chart showing considerable wind speed variation in the northeast corridor between Europe and North America. Figure 5 is a satellite infrared image clearly showing a tropical disturbance southwest of Mexico (not shown in a visible spectrum image). Humidity, temperature and other products are available and the examples shown are typical weather products of interest to pilots.

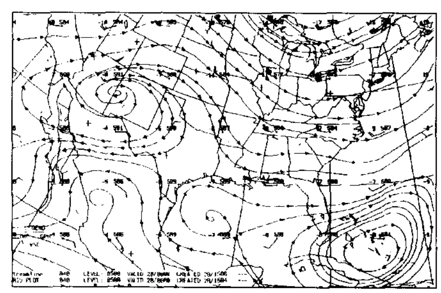
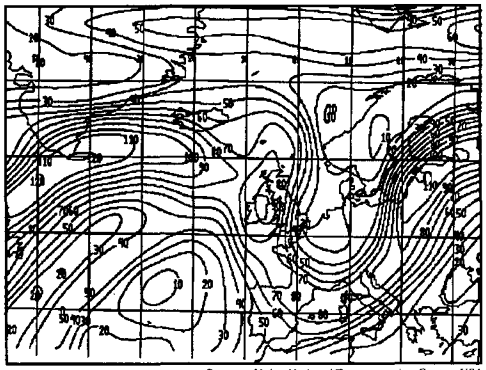


Figure 3. Streamlines or Wind Flows Over the United States AWDS product

En Route Spacing

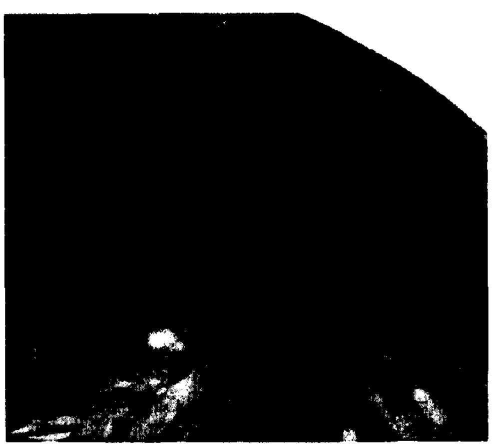
The real-time control of aircraft, especially in the Northeast corridor (Europe to North America), is a critical problem for reasons of air safety, but also represents an opportunity for improved operational efficiency.



Courtesy Volpe National Transportation Center, USA

Figure 4. Wind Flow in the Northeast Corridor

With regards to safety, it is desired to maintain aircraft spacing at five minutes along track; and adjacent flight tracks are spaced at 60 miles. Position updates are collected at 2 minute intervals for aircraft in the northeast corridor. A variety of systems including both over-the-horizon high-frequency (HF) radar and ionospheric communications have been employed in the attempt to maintain or reduce spacing. A given spacing established a maximum density or capacity of the northeast corridor or channel. Automatic dependent surveillance using GPS navigation satellites, together with satellite communications via INMARSAT, should make a significant improvement in the accuracy, precision, and reliability of input position data for airspace control. The critical information would then exist at ground facilities. A return link is needed for control. Furthermore, a collision avoidance system will eventually be provided to further enhance air safety. It would seem appropriate to provide a unified or fused display of the information from the (ground-based) air route surveillance and airborne collision avoidance systems.



Courtesy Volpe National Transportation Center, USA

Figure 5. Infrared Satellite Image

Again, it is suggested that a visual graphical color display would provide the most useful representation of the data. Design of such a display is not trivial. In addition to representing position and velocity along track and in adjacent tracks (essentially in one plane), display of information about the flight planes above and below are also necessary. Thus, the data represents a three-dimensional situation with at least two independent data sources. While alternate blinking displays could be used to separate the surveillance and collision-avoidance data, color might be used instead. Blinking might be used to identify potential hazards that violated a spacing or rate-of-closing criterion.

A conceptual display suitable for color LCD is shown in figure 6. This version may serve as a point of departure but should not be considered as a final recommendation. The center strip represents the assigned flight track and the aircraft icon in the center represents the aircraft having the display. This aircraft is also the center of the coordinate

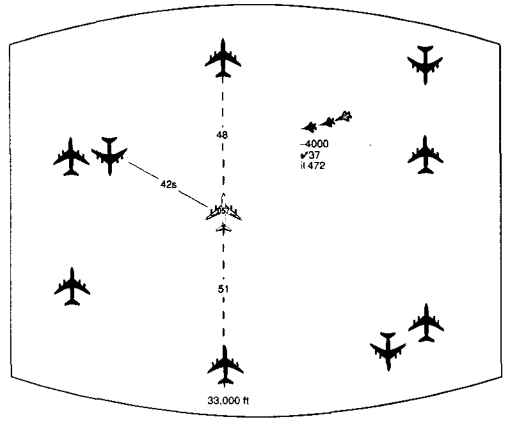


Figure 6. Representative Conceptual Fused Display, Aircraft Position, Velocity Data from Air Traffic Control and On-Board Collision Avoidance Sensors

system for the displayed data. Adjacent tracks are assumed to have aircraft assigned and the spacing is managed to maximize distance between flights. The current separation distance of on-line flights is annotated on the track. Positions of aircraft on the next lower altitude plane are also shown. The icon indicates the direction of flight. For flights within a range threshold or exceeding a closing speed, a vector is drawn with the range or speed provided in numerical form. A military or civilian aircraft, not constrained to fly along the air traffic control tracks or paths, is shown in figure 6. Its altitude, separation and closing speed are all annotated, because they violate assumed criteria. The most recent three positions of this intruding aircraft are shown. Finally, color and/or blinking could be used to annotate different altitudes (planes), or to designate most significant or nearest flights, etc.

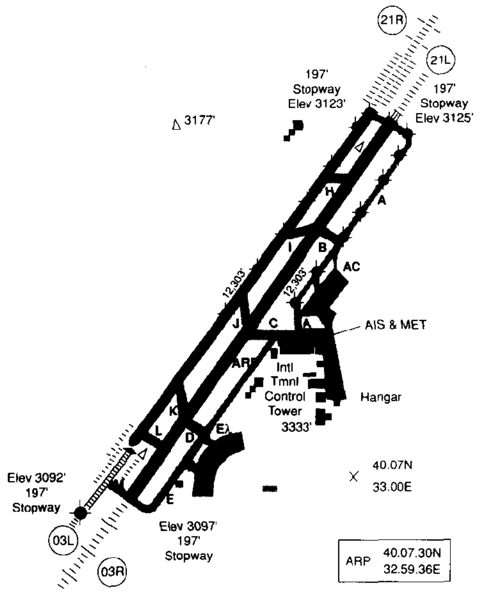
Since the data represents a three-dimensional situation display, some form of isometric view could be employed. A three-dimensional virtual reality display could also be used.

Diverts

Aircraft in flight may be diverted to a different airport for reasons of air traffic or weather, for example. Similarly, a pilot may be able to modify the planned flight trajectory to realize significant improvements in air speed, or reductions in fuel consumption. Real-time control in response to wind and weather would produce significant cost reductions and performance enhancements.

Taxiways and Tarmac Parking

Control of vehicles on the ground is also a critical safety problem. If technology allows reduced in-flight spacing, more frequency landings will result in increased ground



Courtesy Volpe National Transportation Center, USA

Figure 7. Ankara, Turkey Airport Showing Taxiways

traffic congestion. While locating the correct terminal gate would not normally be a problem for commercial passenger aircraft at large international terminals, it can be for significant cargo transport to smaller airports and in military airlifts. Depending on the speed of unloading prior flights, the optimum location for parking may change dynamically as an aircraft approaches touchdown. At very small airports, parking spaces on the tarmac may be limited. Figure 7 shows some details of the Ankara, Turkey airport. The symbols shown along the runway and taxiway indicate position fixes of a particular flight. Obviously, empty (or colored) symbols along the runways or taxiways may be used to indicate filled and vacant parking places that direct inbound aircraft to the assigned location. Again, a visual display, or roadmap, is clearly superior to verbal or textual presentation.

Training/Practice

While the enhancements through graphics presentation of data to the flight deck is valuable in itself, it might be viewed as a portion of an overall improvement that embraces pilot training, preflight mission practice, in-flight control and safety, in-flight weather monitoring, and landing and taxiing. The pilot training and mission practicing phases would be enhanced through virtual reality simulations.

CONCLUSIONS

Graphics and imagery can provide a powerful and effective means of communications to the flight deck of aircraft. It is important that the technology for implementation exists and is undergoing intensive development and rapid improvement, which is in no way dependent on the application to the cockpit. Hence, the operational implementation will enjoy steady improvement in performance, and reduction in cost.

A broadcast function using L-Band, and perhaps most gracefully implemented through INMARSAT, is recommended for the downlink to aircraft. More detailed analysis of traffic is needed to estimate whether a special channel is needed. Features of INMARSAT including spot beams, increased EIRP, and power management flexibility will facilitate implementation. Because of image compression technology, it may be possible to accomplish the aircraft fleet broadcast channel for *cockpit vision* using conventional data rates without a special high power channel.[4]

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